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# Association between nocturnal and diurnal aeration in Nile tilapia rearing tanks

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**ABSTRACT.** The present study has assessed the benefits of the association between nocturnal and diurnal aeration of water on Nile tilapia's culture tanks' water and soil quality, as well as to fish growth performance. There were control tanks without mechanical aeration. In the nocturnal tanks, the aeration was provided daily from 2200 up to 0600. The diurnal tanks were provided with aeration daily from 1000 up to 1800. In the nocturnal and diurnal tanks, the culture water was aerated from 1000 up to 0600. The concentration of $NH_3$ was significantly lower in the diurnal aerated, and nocturnal + diurnal aerated tanks when compared to the non-aerated tanks. The best water quality management to attain simultaneously high $DO_2$ and low $NH_3$ concentration was the nocturnal + diurnal aeration of water. The nocturnal + diurnal aeration of water has not shown any clear advantage on fish growth performance after 10 weeks when compared to the nocturnal aeration of water. It was concluded that the nocturnal + diurnal aeration of water is a water quality management superior to the nocturnal aeration because it achieves a better water quality

**Keywords:** aquaculture, *Oreochromis niloticus*, water quality.

## Associação entre aeração noturna e diurna em tanques de cultivo de tilápia do Nilo

**RESUMO.** O presente trabalho teve por objetivo determinar os benefícios da associação entre a aeração noturnal e diurna da água de tanques de cultivo da tilápia do Nilo, em relação à qualidade de água, do solo e do desempenho zootécnico. Havia tanques sem aeração; tanques noturnos, com aeração fornecida diariamente das 22 às 06h; tanques diurnos, com aeração fornecida diariamente das 10 às 18h; e tanques noturnos + diurnos, com aeração fornecida das 10 às 06h do dia seguinte. As concentrações de $NH_3$ da água de cultivo foram significativamente menores nos tanques diurnos e noturnos + diurnos, quando comparados aos tanques sem aeração. Nos tanques com aeração noturna e diurna se obteve, simultaneamente, elevadas concentrações de $O_2$ dissolvido na água e baixas concentrações de $NH_3$. Embora a aeração noturna e diurna da água não tenha apresentado claras vantagens para o desempenho zootécnico após dez semanas de cultivo, concluiu-se que a associação da aeração noturna com a diurna é um manejo de qualidade de água superior à aeração apenas noturna por propiciar melhor qualidade de água.

**Palavras-chave:** aquicultura, *Oreochromis niloticus*, qualidade de água.

## Introduction

The concentration of dissolved oxygen in water ($DO_2$) is a critical factor for the success of fish culture because it directly affects the respiratory rate of these animals, which influences their survival and growth. When submitted to low levels of $DO_2$, fish generally lose appetite and, consequently, suffer from body growth impairment (Tran-Duy, Schrama, van Dam, & Verreth, 2008). Previous studies have demonstrated that fish have a greater tolerance against ammonia toxicity if living in $DO_2$ rich environments (Thorarensen et al., 2010; Dong, Zhang, Qin, & Zong, 2013). Mechanical aeration is the straightforward management of water quality to provide $DO_2$ to the culture water. Up to a certain limit, the greater the mechanical aeration rate used, the higher the fish stocking density that can be used by the producer (Li, Li, & Wang, 2006). As a rule, the $DO_2$ concentrations in aquaculture waters should be equal or higher than 4 mg $L^{-1}$ to attain better growth results (Boyd, 2000).

The nocturnal aeration of water is the most common regimen of water aeration used in aquaculture. The $DO_2$ concentration of water can be reduced up to zero overnight without proper aeration. Pawar, Jena, Das, and Bhatnagar (2009) and Das, Jena, Mishra, and Pati (2012) have observed significant improvement in fish growth performance due to nocturnal aeration of water. However, despite its clear benefits, the nocturnal aeration of water has its limitations. Kimpara, Santos, and Valenti (2013) have observed that nocturnal aeration of water was not capable to prevent the thermal stratification of water. Silva, Lima, Vale, and Sá (2013) have found that the ammonia removal by the nocturnal aeration of water was insignificant. Furthermore, the nocturnal aeration of water does not prevent the oversaturation of water with $DO_2$, a situation that can cause the gas bubble disease in fish (Espmark, Hjelde, & Baeverfjord, 2010).

Generally, fish farmers turn on their mechanical aerators during daylight just in the rainy or heavily cloudy days. These weather conditions curb photosynthesis and, consequently, elicit low $DO_2$ concentrations in water. Besides, the mechanical aerators can be operated during the daylight to prevent the thermal stratification of water, which can cause anoxia in the pond bottom. Additionally, the use of the aerators in the daylight can reduce the concentrations of ammonia by volatilization (Gross, Boyd, & Wood, 2000), as well as it can prevent the dangerous oversaturation of water with $DO_2$. The cost of aeration is relatively small compared to the value of the aquaculture crop, generally not exceeding 10% of that value (Boyd, 1998). Therefore, it would be reasonable to combine the strengths of the nocturnal and diurnal regimes of water aeration, seeking an even better water quality. The present study has assessed the benefits of the association between nocturnal and diurnal aeration of water on Nile tilapia's culture tanks, in regard to their water and soil quality, as well as to the fish growth performance.

## Material and methods

One thousand masculinized Nile tilapia juveniles, *Oreochromis niloticus* (body weight = 0.75 ± 0.07 g), were obtained from a nearby producer and hauled up to the laboratory facilities. Initially, fish were maintained for four days in one 1,000-L polyethylene circular tank for acclimation. In that period, the animals were fed on a commercial diet for omnivorous tropical fish with 49.4% crude protein. That diet was allowed at 10% of the stocked biomass daily, being evenly split in four meals at 0800, 1100, 1400 and 1700.

The study was carried out in the outdoor culture system of the laboratory, which is comprised by twenty 250-L polyethylene circular tanks. At the onset of the experiment, Nile tilapia juveniles (body weight = 1.03 ± 0.02 g) were equally allotted into the culture tanks at eight fish per tank (32 fish $m^{-3}$). The culture tanks were submitted to different water aeration regimes for 10 weeks. There were three control groups and one experimental treatment, each one with five replicates. There were also tanks that have not received any mechanical aeration over the entire experimental period (non-aerated tanks). In the nocturnal tanks, the mechanical aeration was provided daily from 2200 up to 0600 (8 hours of aeration daily). The diurnal tanks were provided with mechanical aeration daily from 1000 up to 1800 (8 hours of aeration daily). In the nocturnal + diurnal tanks, the culture water was aerated from 1000 up to 0600 (20 hours of aeration daily). The mechanical aeration of the culture water was provided by one 2.5 hp air blower, which was connected to PVC pipes and air stones. The water aeration started at the 3rd experimental week to simulate a commercial fish farm schedule remaining until the end.

Over the entire experimental period, fish were fed on commercial diets at 0800, 1100, 1400 and 1700. No water exchange was performed over the whole period, just replenishment to maintain the initial level. The tank bottom was filled with a 5-cm layer of gross sand to allow water-soil interactions.

The water quality of the culture tanks was monitored by regular observations of the following variables: (1) pH (pH meter mPA210 - MS Tecnopon), (2) temperature and specific conductance at 0900 and 1500 (conductivity meter CD-4303 – Lutron), (3) dissolved oxygen (0800; dissolved oxygen meter YSI 55), (4) total ammonia nitrogen (TAN; indophenol method), (5) nitrite (sulfanilamide method), (6) free $CO_2$ (titration with standard $Na_2CO_3$ solution), (7) reactive phosphorus (molybdenum blue method), (8) total alkalinity (titration with $H_2SO_4$ standard solution), (9) total hardness (titration with EDTA standard solution), (10) soluble iron (colorimetric Herapath method) and (11) total dissolved sulfide (titration with standard $Na_2S_2O_3$ solution). The water quality variables were monitored daily (1), twice a week (2), weekly (3, 4) and fortnightly (5 – 11). The water samplings were always carried out between 0800 and 0900. The Emerson's formula (El-Shafai, El-Gohary, Nasr, van der Steen, & Gijzen, 2004) was used to estimate the concentration on non-ionized ammonia ($NH_3$) in water. The $H_2S$ concentration of water was estimated according to Boyd (2000). Except when stated otherwise, all water quality determinations were carried out according to Clesceri, Greenberg, and Eaton (1998). The gross primary productivity was determined by the clear and dark bottle method. The soil determinations of pH and organic carbon were carried out every other week following the guidelines provided by Boyd, Wood, and Thunjai (2002). In the week before the last one (9th week), the temperature, pH and concentrations of TAN, $NH_3$ and $DO_2$ in water were observed on a diel basis (24 h). For that, water samplings were collected every two hours.

The variables of growth performance analyzed were: survival (%), fish final body weight (g), specific growth rate (% $day^{-1}$; SGR = [Ln (final weight) - Ln (weight initial)]/ days of culture) x 100), weekly growth rate (g), fish yield (g $m^{-3}$ $day^{-1}$), food conversion ratio (FCR = feed consumed/ body weight gain), and protein efficiency ratio (PER = weight gain /protein consumed).

The final results of water quality and growth performance were analyzed by the one-way ANOVA. When a significant difference was detected between the treatments ($p < 0.05$), the means were compared two by two with the Tukey's test. The assumptions of normal distribution (Shapiro-Wilk's test) and homogeneity of variance (Levene's test) were checked before the analyses. The SPSS v.15.0 and Windows Excel 2010 software were used for the statistical analyses.

## Results and discussion

### Water and soil quality

In the non-aerated tanks, the concentrations of $DO_2$ in water declined progressively over time reaching 2.61 ± 1.61 mg $L^{-1}$ at the end of the period. The same trend was seen in the diurnally aerated tanks, which exhibited a final $DO_2$ concentration of 2.15 ± 1.00 mg $L^{-1}$ (Figure 1). Those two $DO_2$ results have not significantly differed between themselves ($p > 0.05$). As expected, the nocturnal aeration of water has avoided the decrease of $DO_2$ in water over the experimental period. The final $DO_2$ concentration in the nocturnal tanks was 6.12 ± 1.64 mg $L^{-1}$. A similar result was found in the 20-h aerated tanks, i.e., those tanks with nocturnal + diurnal aeration. Their final $DO_2$ concentration was 6.42 ± 0.5 mg $L^{-1}$ (Figure 1). Those two $DO_2$ results have not differed significantly between themselves ($p > 0.05$). Therefore, there is no rationale in associate the nocturnal with the diurnal aeration of water aiming just higher $DO_2$ levels in water.

In green waters, the concentrations of $DO_2$ during the daylight increase due to photosynthesis. It is common to have waters supersaturated with $DO_2$ over the afternoons. There is a withdrawal instead of an input of $DO_2$ when aerators are applied in supersaturated $DO_2$ waters (Ludwig, 2003). In non-aerated tanks, the absence of photosynthesis during the night causes a fast decline in the concentrations of $DO_2$ in water (Alam & Al-Hafedh, 2006).

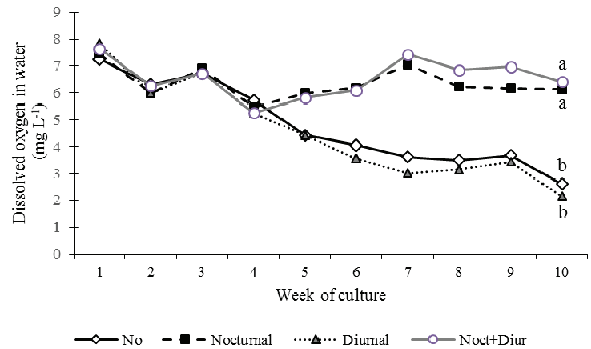


**Figure 1.** Concentration of dissolved oxygen in water at 0800 of Nile tilapia tanks submitted to different water aeration regimes (n = 5). Nocturnal aeration: 2200 – 0600; diurnal aeration: 1000 – 1800; nocturnal + diurnal aeration: 1000 – 0600. In the last week, symbols with distinct letters represent means significantly different between themselves by the Tukey's test (ANOVA, $p < 0.05$).

The concentrations of $NH_3$ in the culture waters have increased progressively in all tanks over time (Figure 2). There was a sharp increase in the concentrations of $NH_3$ beyond the 8th experimental week, especially in the non-aerated and nocturnally aerated tanks. At the end of the experimental period, the concentrations of $NH_3$ were significantly lower in the diurnally aerated, and nocturnal + diurnal aerated tanks when compared to the non-aerated tanks ($p < 0.05$). The results on Figure 2 suggest that the diurnal aeration of water removes more ammonia than nocturnal aeration. However, as the diurnal aeration was unable to maintain high levels of $DO_2$ during the night, the best water quality management to attain simultaneously high $DO_2$ and low $NH_3$ concentrations is the nocturnal plus diurnal aeration of water. Silva et al. (2013) have also observed a decrease in the concentrations of ammonia in continuously aerated Nile tilapia rearing tanks. The decrease of total ammonia was probably due to the volatilization of gaseous $NH_3$ carried out by the diurnal aeration. There is a natural rising in the concentrations of $NH_3$ in water as the temperature and pH of water increase over the afternoons. Therefore, afternoon is the best period of the day to remove $NH_3$ by volatilization. According to Gross, Boyd, and Wood (1999), $NH_3$ volatilization can withdraw a significant amount of ammonia from water. Gross et al. (2000) has observed that 12.5% of the total ammonia in American catfish tanks was removed by volatilization.

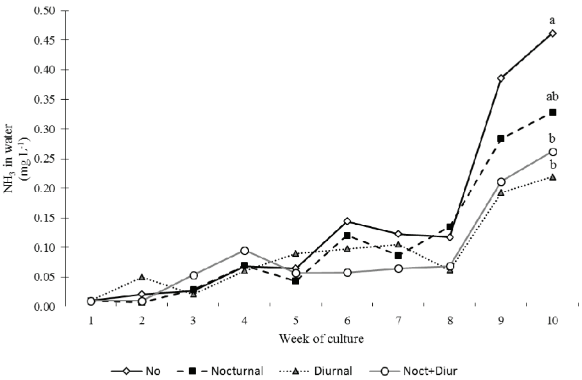


**Figure 2.** Concentration of non-ionized ammonia ($NH_3$) in water between 0800 and 0900 of Nile tilapia tanks submitted to different water aeration regimes (n = 5). Nocturnal aeration: 2200 – 0600; diurnal aeration: 1000 – 1800; nocturnal + diurnal aeration: 1000 – 0600. In the last week, symbols with distinct letters represent means significantly different between themselves by the Tukey's test (ANOVA, $p < 0.05$).

Temperature, pH, specific conductance, total alkalinity and total hardness of water have not differed significantly between the treatments (29.4 ± 0.07°C, 8.52 ± 0.05, 924 ± 29 $\mu$S $cm^{-1}$, 143.9 ± 6.5 mg $L^{-1}$ $CaCO_3$ and 193.7 ± 2.7 mg $L^{-1}$ $CaCO_3$ respectively; Table 1). Similarly, the concentrations of soluble iron, total sulfide and the gross and net primary productivities have also not significantly varied between the treatments (0.44 ± 0.19 and 1.49 ± 0.67 mg $L^{-1}$, 0.89 ± 0.14 and 0.60 ± 0.14 mg $O_2$ $L^{-1}$ $hour^{-1}$, respectively; Table 1).

The lowest concentrations of free $CO_2$ in water were observed in the nocturnal + diurnal aerated tanks, which differed significantly from the non-aerated tanks ($p < 0.05$; Table 1). The nocturnal aeration of water is prone to remove significant amounts of $CO_2$ from the water because the highest levels of $CO_2$ occur overnight (Abbink et al., 2012).

There was a significantly lower concentration of nitrite ($NO_2^-$) in the nocturnal + diurnal aerated tanks (Table 1; $p < 0.05$). This result agrees with Avnimelech, Mozes, and Weber (1992), who observed lower concentrations of nitrite in continuously aerated tanks, and with Lima, Cavalcante, Rebouças, and Sá (2016), who concluded that the afternoon aeration of water is an efficient management to remove nitrite from fish tanks. Although that seems promising, it is probably cheaper to apply common salt to the culture water aiming at lessening nitrite toxicity.

**Table 1.** Water quality of Nile tilapia tanks submitted to different water aeration regimes for 10 weeks. The results were obtained over the last water quality monitoring carried out (mean ± d.p.; n = 5).

| Variable[2] | Water aeration schedule[1] | | | |
|---|---|---|---|---|
| | No | Nocturnal | Diurnal | Noct + Diur |
| Temp 9 am | 27.8 ± 0.2 | 27.7 ± 0.2 | 27.8 ± 0.1 | 27.6 ± 0.2 |
| Temp 3 pm | 31.0 ± 0.8 | 31.1 ± 0.7 | 31.1 ± 0.7 | 30.9 ± 0.9 |
| SC 9 am | 917 ± 30 | 927 ± 25 | 920 ± 28 | 929 ± 33 |
| SC 3 pm | 933 ± 22 | 935 ± 27 | 928 ± 31 | 936 ± 36 |
| pH | 8.44 ± 0.25 | 8.53 ± 0.17 | 8.50 ± 0.16 | 8.60 ± 0.20 |
| TA | 153 ± 12 | 141 ± 9 | 141 ± 4 | 138 ± 2 |
| TH | 197 ± 7 | 191 ± 8 | 193 ± 3 | 192 ± 7 |
| Free $CO_2$ | 8.53 ± 1.92 a[3] | 6.57 ± 0.64 ab | 7.24 ± 1.01 ab | 6.04 ± 1.30 b |
| $NO_2^-$ | 0.15 ± 0.02 a | 0.15 ± 0.03 a | 0.12 ± 0.04 a | 0.06 ± 0.02 b |
| P-Reac | 0.25 ± 0.09 a | 0.10 ± 0.04 b | 0.12 ± 0.07 b | 0.12 ± 0.03 b |
| $Fe^{+2}$ | 0.48 ± 0.22 | 0.37 ± 0.19 | 0.44 ± 0.12 | 0.46 ± 0.25 |
| GPPP | 0.97 ± 0.20 | 0.84 ± 0.18 | 0.87 ± 0.11 | 0.90 ± 0.08 |
| NPPP | 0.58 ± 0.14 | 0.53 ± 0.16 | 0.71 ± 0.13 | 0.59 ± 0.14 |
| Total sulfide | 1.96 ± 0.58 | 1.23 ± 0.55 | 1.55 ± 0.69 | 1.25 ± 0.87 |
| $H_2S$ | 0.45 ± 0.14 a | 0.17 ± 0.05 b | 0.25 ± 0.07 a | 0.17 ± 0.16 b |

[1]Nocturnal aeration: 2200 – 0600; diurnal aeration: 1000 – 1800; nocturnal + diurnal aeration: 1000 – 0600. [2]Temp 9 am and 3 pm: temperature at 9 am and 3 pm (°C), SC 9 am and 3 pm: specific conductance at 9 am and 3 pm ($\mu$S $cm^{-1}$), TA: total alkalinity (mg $L^{-1}$ $CaCO_3$), total hardness (mg $L^{-1}$ $CaCO_3$), Free $CO_2$ (mg $L^{-1}$), $NO_2^-$ nitrite (mg $L^{-1}$), P-reactive (mg $L^{-1}$), $Fe^{+2}$ soluble iron (mg $L^{-1}$), GPP: gross primary productivity (mg $O_2$ $L^{-1}$ $hour^{-1}$), net primary productivity (mg $O_2$ $L^{-1}$ $hour^{-1}$), total sulfide (mg $L^{-1}$), $H_2S$ (mg $L^{-1}$). [3]For a same variable, means not sharing a same letter are significantly different between themselves by the Tukey's test. Absence of letters indicates that no significant differences exist between the means. The significant ANOVA P values were the following: free $CO_2$ (0.043), $NO_2^-$ (0.001), P-React (0.003) and $H_2S$ (0.005).

The aeration of water, regardless its regimen (nocturnal, diurnal, and nocturnal + diurnal), has significantly decreased the concentrations of reactive phosphorus in water (Table 1; $p < 0.05$). In well-aerated waters, a superficial oxidative layer is formed onto the sediments, which avoids or minimizes the diffusion of soluble phosphorus from the underlying soil to the water column. Besides, the phosphates tend to precipitate to the bottom in well-oxygenated waters (Wu, Wen, Zhou, & Wu, 2014).

The concentrations of $H_2S$ in water were reduced by water aeration, mainly in the nocturnal, and nocturnal + diurnal regimes (Table 1; $p < 0.05$). At night, the decrease of water pH promotes the formation of $H_2S$ according to the following reaction: $H_2S \leftrightarrow HS^- + H^+$ (Blodau, 2004). Therefore, nocturnal aeration is capable to significantly reduce the concentrations of $H_2S$ in water by volatilization.

The differences between the treatments for soil pH were not significant ($p > 0.05$). No clear pattern was seen for the variations of soil pH over time, an observation also made by Pawar et al. (2009) in a carp study. On average, the pH of soil in the experimental tanks was 7.82 ± 0.24. The concentrations of organic carbon in soil increased in all treatments over time (Figure 3). Significantly more organic carbon was observed in the non-aerated tanks' soil on the 8th experimental week ($p < 0.05$). Higher rates of organic matter mineralization are expected in well-aerated waters than in the hypoxic ones, such as those in the non-aerated tanks.

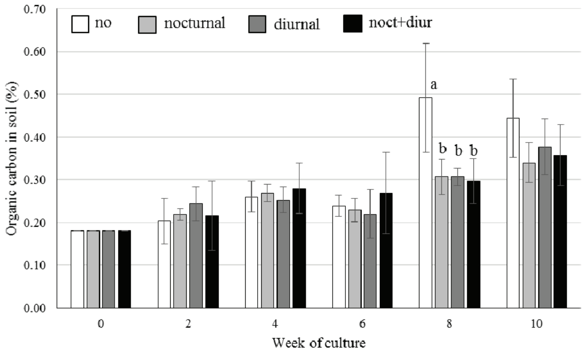


**Figure 3.** Concentration of organic carbon in Nile tilapia tanks' soils. The tanks were submitted to different water aeration regimes for 10 weeks (n = 5). Nocturnal aeration: 2200 – 0600; diurnal aeration: 1000 – 1800; nocturnal + diurnal aeration: 1000 – 0600. Columns with distinct letters represent means significantly different between themselves by the Tukey's test (ANOVA, $p < 0.05$). Absence of letters indicates no significant differences between the means.

## Diel water quality monitoring

Over the diel monitoring, the temperature, pH and concentrations of $DO_2$ and $NH_3$ increased during the daylight up to 1400 – 1600 and decreased afterwards until the next morning (Figure 4). The non-aerated and diurnally aerated tanks showed concentrations of $DO_2$ below 4 mg $L^{-1}$ from 2000 to 0800. In those tanks, the $DO_2$ concentrations were as low as 0.25 mg $L^{-1}$ at 0600. On the other hand, the $DO_2$ concentrations were always above 4 mg $L^{-1}$ in the diurnally, and nocturnally and diurnally aerated tanks, for that same period (Figure 4). Interestingly, the $DO_2$ concentrations in the middle of the afternoon for the diurnally, and nocturnally and diurnally aerated tanks were markedly lower than those for the non-aerated, and nocturnally aerated tanks. That fact points out that the aeration of water over the warmest and lightest hours of the day helps to lessen the $DO_2$ supersaturation of water. The supersaturation of water with $DO_2$ may be troublesome because it can cause the gas bubble disease in fish (Salas-Leiton et al., 2009). The variations of TAN in water over 24 hours have not presented distinct patterns for any of the water aeration regimes considered. At 1400, there was less $NH_3$ in the nocturnally and diurnally aerated tanks than in the nocturnally aerated ones (Figure 4). This result strengthens the previous suggestion that afternoon is the best period of the day to remove water $NH_3$ by volatilization.

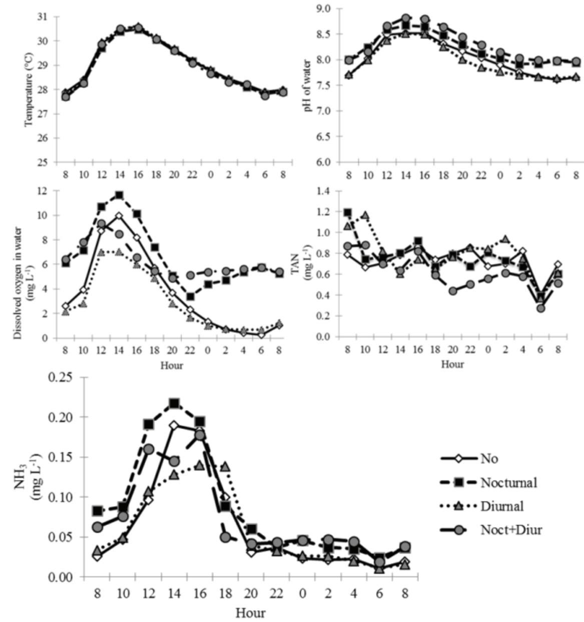


**Figure 4.** Diel variations of temperature, pH, total ammonia nitrogen (TAN), $NH_3$ and dissolved oxygen ($DO_2$) in tanks submitted to different water aeration regimes for 10 weeks (n = 5). Nocturnal aeration: 2200 – 0600; diurnal aeration: 1000 – 1800; nocturnal + diurnal aeration: 1000 – 0600.

## Growth performance

Fish survival was greater than 90% in all treatments and there were no significant differences between them. The results of final body weight, specific growth rate, weekly weight gain, fish yield and PER for the nocturnally, and nocturnally and diurnally aerated tanks were significantly higher than those on the non-aerated tanks (Table 2; ANOVA, $p < 0.05$). Similarly, the best FCR results were observed in the nocturnally, and nocturnally and diurnally aerated tanks. No significant differences were found between those two treatments for any of the growth performance variables. Kimpara et al. (2013) obtained similar results in a *Macrobrachium rosenbergii* study. Therefore, no clear advantage can be drawn from the nocturnal + diurnal aeration of water in relation to fish growth performance when compared to the nocturnal aeration of water.

The significantly lower concentrations of nitrite in the nocturnally and diurnally aerated tanks, when compared to the nocturnally aerated ones (Table 1), were not capable to improve fish growth performance in the former tanks. However, it is hypothesized that the better water quality in the nocturnally and diurnally aerated tanks can improve fish growth in more stressful culture media, such as those where fish is submitted to high stocking densities. The profitability of nocturnal plus diurnal aeration management, however, needs to be assessed in further studies.

**Table 2.** Growth performance of Nile tilapia juveniles (initial body weight = 1.03 ± 0.02 g) stocked in outdoor tanks submitted to different water aeration regimes for 10 weeks (mean ± d.p.; n = 5).

| Variable[2] | Water aeration schedule[1] | | | |
|---|---|---|---|---|
| | No | Nocturnal | Diurnal | Noct + Diur |
| Survival | 90.6 ± 5.4 | 95.0 ± 11.2 | 90.0 ± 10.5 | 90.0 ± 5.6 |
| FBW | 21.6 ± 1.0 b[3] | 29.1 ± 4.2 a | 25.2 ± 2.8 ab | 30.0 ± 3.2 a |
| SGR | 4.30 ± 0.05 b | 4.76 ± 0.17 a | 4.59 ± 0.19 ab | 4.83 ± 0.20 a |
| WWG | 1.64 ± 0.92 b | 2.81 ± 0.42 a | 2.42 ± 0.28 ab | 2.89 ± 0.32 a |
| Fish Yield | 8.9 ± 0.4 b | 12.5 ± 0.6 a | 10.3 ± 0.7 b | 12.3 ± 1.6 a |
| FCR | 1.11 ± 0.02 c | 0.83 ± 0.07 a | 0.98 ± 0.06 b | 0.83 ± 0.08 a |
| PER | 2.46 ± 0.05 b | 3.39 ± 0.24 a | 2.80 ± 0.17 b | 3.24 ± 0.31 a |

[1]Nocturnal aeration: 2200 – 0600; diurnal aeration: 1000 – 1800; nocturnal + diurnal aeration: 1000 – 0600. [2]Survival (%), FBW: final body weight (g), Specific growth rate (% $day^{-1}$) = (ln final body weight – ln initial body weight)/ days of rearing *x* 100, WWG: weekly weight gain (g), Fish yield (g $m^{-3}$ $day^{-1}$), FCR: food conversion ratio = manufactured food intake/ body weight increase, PER: protein efficiency ratio = weight gain/ protein intake. [3]For a same variable, means not sharing a same letter are significantly different between themselves by the Tukey's test. Absence of letters indicates that no significant differences exist between the means. The significant ANOVA p values were the following: FBW (0.004), SGR (0.004), WWG (0.003), Fish yield (0.001), FCR (< 0.001), PER (0.001).

## Conclusion

The best water quality management to attain simultaneously high $DO_2$ and low $NH_3$ is the association between nocturnal and diurnal aeration of water.

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